THE GLACIAL PERIOD IN AUSTRALIA.

Plates VII. and VIII.

By R. von Lendenfeld, Ph.D.

Introduction.

During a recent expedition to the central part of the Australian Alps I have discovered undoubted traces of ancient glaciers, and can assert accordingly that Australia also has passed through a glacial period.

Before entering into a description of my discoveries, I think it my pleasant duty to express my thanks to those who materially assisted me in the accomplishment of my work, by lending me instruments and maps, and many other services.

The Hon. Mr. Abbott, the Minister for Mines, supplied me with railway passes, for which I am particularly indebted to him. The Surveyor-General supplied me with several instruments and maps, and I am also indebted to him for many practical hints drawn from his own experience on the mountain.

Mr. Wilkinson, the Government geologist, supplied me with instruments and his assistant, Mr. Cullen, rendered me invaluable services during the expedition; also in other ways Mr. Wilkinson aided me very much in my research. The greatest practical assistance was rendered me by Mr. Betts, the district surveyor at Cooma, to whose energy and chivalrous courtesy alone our advance was made possible, and the difficulty of getting along the bulky luggage, provisions, instruments, &c., overcome.

Literature.

In literature there are a few statements regarding the ancient glaciation of Australia, but they are all very vague or made by people of not sufficient practical alpine experince. I shall review what I have found in a few words.

Tenison-Woods (1) says—"There is no satisfactory evidence of a former participation in the great ice age by the continent of Australia. One or two instances of grooves or striations are recorded, but standing alone in so vast a territory the ice origin is very doubtful."

Howitt (2) says—"Nowhere in Gippsland have I been able to detect any appearances which I could in any away refer to a glacial period, analogous to that of the Northern Hemisphere. I have nowhere met with grooved or scratched rocks, erratic boulders, moraines, or any traces of ice action." He goes on to say that the ancient lake-basins near Omeo might suggest the action of ice.

Whilst these two authors do not believe in a glacial period having ever occurred in Australia, Professor Tate and Mr. Griffiths assert that there are such traces, but their observations are very vague, and it appears that these gentlemen as well as those mentioned above, had looked for glacier remains altogether in the wrong places.

Professor Tate (3) states that he found erratic boulders and striated rock surfaces on the beach near Adelaide. To look for glaciers one must go up the mountains not down to the sea.

The evidence collected by Professor Tate proves by no means that any glaciers had ever existed in Australia, and it is probable that the erratics found by him were deposited on the beach by ice bergs stranded there, which may have drifted to the South Coast of Australia, from the South Pole at the time when it was colder in the southern hemisphere than it is at present.

Mr. Griffith's (4) evidence is of a still more vague character; he finds a lot of gravel and clay, and concludes that this must have been formed by glacial action. Mr. Griffiths did not however,

(1) *Tenison-Woods.* Physical structure and geology of Australia. Proceedings of the Linnean Society of New South Wales. Vol. VII., p. 382.
(2) *Howitt.* Geology of North Gippsland, Victoria. Quarterly Journal of the Geological Society of London. Vol. XXXV., p. 35.
(3) *Tate* Anniversary Address to the Royal Society of Transactions of the Royal Society of South Australia, 1878—1879.
(4) *Griffiths.* On the Evidences of a Glacial Epoch in Victoria during past miocene times. Royal Society of Victoria, 1882.

take the trouble to go up to the place where all this gravel and clay was said to have been brought down from, so that, as he himself states, his evidence is very unsatisfactory. He also tries to bring some other geological facts in connection with a glacial period. I however, perfectly agree with Hutton (1), that all the formations referred to by Mr. Griffiths, could just as well have been formed in another way, and I do not think it likely that Mr. Griffith's clays and gravels are of glacial origin.

Own Observation.

Every child in the European Alps knows that glaciers are formed on mountains and nowhere else. So if one wants to find glacial remains, of course up the mountains one must go. If the glaciers at any time since the land has attained its present shape, have extended so far as Tate and Griffiths assert, if the Omeo Lake has been scooped out by glacier ice which Howitt considers possible, how much clearer must the evidence of glaciers be then, in the heart of the mountains down the sides of which they must have extended and where they must have originated.

On the other hand, if no evidence of glacial action is found in the low lands, that is no reason why glaciers could not have been present on the slopes of the highest mountains.

It is quite evident from this, that the glacial traces must be looked for in the mountains first, and then, when the existence of traces of prehistoric glaciers there have been found, the investigation can be extended down to the low lands to ascertain how far the glacies reached. The gentlemen mentioned above never took the trouble to look for the glacial traces in the alpine valleys, so that of course no reliance whatever can be placed on their statements where negative, and even where positive, they will not be satisfactory.

On these grounds I undertook an expedition to the highest mountains in Australia, knowing that I could easily decide the question of pre-historic glaciation there.

(1) *Hutton.* The Origin of the Fauna and Flora of New Zealand, part II., p. 16.

Between the sources of the Murray in the west and the sources of the Snowy River in the east, there lies an extensive plateau on an average about 5000 feet high and extending over about 160 square miles. This plateau extends N. and S. for about 22 miles, and has an average breadth of 8 miles. A mile to the east of the western margin of the plateau the main range is situated extending in the same direction as the plateau from N. to S. In that part of the main range lies the highest mountain in Australia which I mapped, measured, and ascended for the first time, 7256 feet high, Mount Townsend. In a western secondary range, a mile to the north of my highest peak, another mountain is situated, which has been frequently ascended and which is crowned by a stone cairn. This latter has the name Mount Kosciusco or Mueller's Peak, and is 7171 feet high. Round about on this plateau there are numerous hills over 7000 feet in height, and the flat extended bottoms of some of the valleys lie about 6000 feet high.

Even now we find small patches of snow lying on the south-eastern face of the ranges, the remnants of snow drifts all the year round in heights above 6500 feet. These snow patches are never found in "deep ravines" as Mr. T. Stirling (1) states. Snow patches such as those on Kosciusco only lie close to the exposed parts where the wind blows a great amount of snow together and stores it for the summer.

Where eternal snow is to be found even now there glaciers must have been at the time of the glacial period, if it ever existed. I found in reality, as I anticipated, most beautiful and indubitable traces of glacial action in these valleys, and I conclude from my observations that the glaciers of that, very recent, glacial period in Australia, covered a part of the plateau mentioned and extended over about 100 square miles.

The evidence of glacial action which I discovered were rôches montonnées, glacier polished rocks, in several places above 5800 feet. Wherever the rocks protrude from the face of a mountain

(1) *Stirling.* Remarks on the Flora of the Australian Alps, &c. Souther Science Record, January, 1885, p. 12.

to form a spur there particularly, but also at other places, one may expect to find these traces. The ice-stream moving down the valley presses with the greatest force against the *protruding* parts of the sides of the valleys on the way, against the spurs. Any rocks or small stones which may have been accidentally frozen into the ice, and which may be situated near the bottom, will, when hard and protruding, cut deep grooves in the rocks which they pass over slowly, with the immense pressure of the whole glacier behind them. In this way the protruding rocks will be polished down more and more. As soon as the glacier retreats these polished rocks will be left bare and exposed to the air.

In our case these rocks are granite without exception, and their surface withers very fast. The grooves and scratches soon become oblitered, but the shape of the extensive polished surface remains and indicates to an experienced eye immediately the action of moving ice.

Further proofs for the correctness of the supposition that we have to do with the effects of ice, are furnished by the relative position of joints and surface. The polishing goes on of course quite regardless of joints, and consequently in 99 cases out of a hundred, one will find the polished surface cutting the joints at varying angles, and not parallel to the direction of any one system of joints.

I have examined the direction, dip, &c., of joints in 12 of the rocks which I consider as glacier polished, and found in every case that the direction of the polished surface followed the direction of the valley, the direction in which the glacier there, once had moved, and was never parallel with any system of joints. The rounded, always convex shape, and particularly also one fact proves the glacial origin of these surfaces without a doubt—viz., that the polished surface is *continuous* for a long distance in some places. That is to say, in those parts numerous isolated rocks, in different parts of the hill side or spur, are polished down to exactly the same level.

One of these instances, on a spur high above a tributary to the Snowy River, was so remarkable, that my assistant, who had never

seen any rôches moutonnées in his life before; was immediately very much struck by the appearance of it.

There, there is one rock polished off with a surface of about 3 acres and about 25 other much smaller ones around it, all polished down to exactly the same surface, divided from one another however by depressions of varying depth.

The most numerous and the best preserved of these rôches moutonnées are found in a valley, which I name after our President the Government Geologist, Wilkinson Valley. As I have studied this valley most minutely and as it is doubtless the highest valley in Australia, I shall describe it and also the glacier which at one time filled it.

On Plate 7 and 8, the Wilkinson Valley is represented, as seen from Mount Townsend, which I ascertained to be the highest peak in Australia. The Wilkinson Valley is enclosed by the Abbott Range and Müller's Peak in the north and north-west, by the Main Range for a mile on the east and by the Wilkinson Range on the south-east. Its main direction is from N.E., to S.W. For the upper three miles of its length its bottom is broad and flat and lies very high, forming part of the Kosciusco plateau, Then the fall which is only about three feet to the mile in the upper part rapidly increases and at the same time the valley becomes quite narrow so as to represent a steep ravine.

From the Abbott Range a broad spur descends in a southerly direction into the upper flat part of this valley and forces the stream in its bottom to curve round in the same direction.

On the sides of this valley but particularly on this spur rôches montonnées are very numerous and it is easy to see how far the glacier reached up the hill side by the extent of these glacier polished rocks.

In plate 7, this spur with the polished rocks is seen "en face" just opposite.

Plate 8, represents the probable shape and size of the glacier when it filled that valley. Of course I name the glacier after the valley which it helped to scoop out.

The picture is the same as plate 7, and I have drawn the glacier to that height, at which rôches moutonnées were observed by me. The other parts are of course drawn without regard to the denudation since then, and I have used my alpine experience in giving a picture of the distribution of rock and snow, as it would probably be in summer, were Australia now subjected to a glacial period.

To those who have not seen the glaciers in the high alps, the picture will convey a better idea of the character of the country at that time than any description.

The picture pretends to nothing but a hypothetical value, and will, I hope, be judged accordingly.

Conclusions.

On going to the place where glacier traces might have been expected, these were found in the shape of rôches moutonnées, scattered over an area of about 100 square miles on a plateau above 5,800 feet.

That part of Australia was therefore not so long ago certainly covered by ice.

The question arises whether the glaciers did not extend further down than that. I have looked carefully around on my way up and down the mountain, but I was not able to detect any trace of glacial action below 5,800 feet. In the Snowy Valley a glacier might be expected to have descended for some distance from the mountains, and I think it very likely that moraines will eventually be found there. This valley is, however, the only one in which moraines may be expected, because it is the only one which comes down from an extensive plateau on which a glacier was formed.

It is difficult to fix the time of the glacial period, but it is evident that it was in all probability simultaneous with the glacial period in New Zealand.

According to von Haast (1) the glaciers there descended at that time into the sea on one side and down to a height of a few hundred feet on the other. In New Zealand there are high

(1) *Von Haast.* Geology of Canterbury and Westland.

mountains on the slopes of which the glaciers were formed, and New Zealand also lies further south than Mount Kosciusco. Further there is no doubt that there were warm dry winds from the interior of Australia blowing over the Kosciusco plateau at the time of the glacial period as they do now, winds which must have diminished the size of the nevées very considerably.

Taking all this into consideration we must come to the conclusion that the glaciers of the glacial period in Australia need not have been very extensive, even if nearly the whole of the middle Island of New Zealand were covered by eternal ice at the time.

Hutton (1) is not inclined to believe that the glacial period in New Zealand was so severe as is generally believed, in consequence of the great abundance of animal life at that time. I must say that I do not see this at all. Chamois and many other mammals, as well as birds, live always high above the glacial terminations in summer and winter in Europe, so that there is no reason to suppose that there should not have been an abundance of animal life even if the glaciers had extended further than von Haast (2) states. Hutton (l.c.), is quite right when he says, that if the glaciers in Australia had had that extent which Griffiths supposed, that then the climate in the South Island of New Zealand (I suppose the Middle Island is meant), would have been polar.

This certainly was not the case, as the fossil fauna shows, and therefore, the simultaneous glacial period in Australia could not have been very severe as Hutton very ingeniously concludes.

My own observations tend to prove the correctness of his statements, and the extent of glaciers in the glacial period of Australia according to my observations, is quite in accordance with the much greater extent of glaciers in New Zealand.

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(1) *Hutton.* The Origin of the Fauna and Flora of New Zealand. Part II., p. 16.

(2) *Von Haast.* Geology of Canterbury and Westland.

The state of preservation of the rôches moutannées in the Australian Alps, is nothing like so good as in the New Zealand Alps. I am, however, not inclined to ascribe that to a difference in age. I consider it simply as a consequence of the difference in the rocks; there hard metamorphised slates, here granite.

The difference between diurnal and nocturnal temperature will doubtless also be much greater on Kosciusco, with a continental climate, and nearer the equator, than in New Zealand where an island climate prevails, and where the sun is never so hot in the day time.

I have in another paper (1) drawn attention to the immense amount of weathering caused by differences of temperature, and I think that the rocks on Kosciusco are accordingly exposed to a much more energetic processs of weathering than those in New Zealand.

These differences I think suffice to explain the difference of preservation of the polished rocks in Australia and New Zealand, and I believe I am therefore justified in considering the glacial period of Australia and that of New Zealand to be isochrone.

In another paper (2) I have tried to show that this latter was very recent, and we should in that case have to assume that also the Australian glacial period had occurred at a relatively recent date.

Result.

1. At the time of the glaciation of the Southern Hemisphere, Australia was subjected to a glacial period as well as New Zealand.

2. The climate was then not very cold so that the glaciers only covered the highest part of the Australian Alps, and were consequently very small.

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(1) *Von Lendenfeld.* Der Tasman Gletscher und seine Umgebung. Ergänzungsheft, Nr. 75 zu Petermanns geografischen Mittheilungen. Seite 42.

(2) *Von Lendenfeld.* The time of the glacial period in New Zealand. Proceedings of the Linnean Society of New South Wales. Vol. IX., p. 806.

3. One glacier system has been discovered on the highest part of the Australian Alps. The glaciers extended from a high plateau—Mount Kosciusco—down into the valleys around. The glacial area may be estimated at at least 100 square miles. There were small glaciers at the source of the Murray, not extending far down the plateau, there was a small glacier at the head of the Crackenback. The largest glacier filled the valleys at the sources of the Snowy River and probably extended for some distance down the Snowy Valley.

4. As even on the highest elevation the glaciers were so small it is not likely that glaciers existed anywhere else in Australia at the time.

5. The glacial period in Australia was probably isochrone with a pluviatile period, when the rivers were large and when there was a dense vegetation in many parts of the country which now are barren, and which was sufficient to feed the gigantic Diprotodon and other fossil marsupials.

EXPLANATION OF PLATES.

Plate 7.—Muller's and Abbott Peak and Wilkinson Valley from Mount Townsend from a sketch taken by the Author on 11th January, 1885.

Plate 8.—The same as it would appear in the glacial period.